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THE DETERMINATION AND COMPARISON OF THE GRARR MADGAR SITE LOCATION

by

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ABSTRACT

Improved coordinates for the Goddard Range and Range Rate (GRARR) station at Madagascar (MADGAR) range and rate site have been estimated from GEOS I data sets using the NONAME Orbit Determination Program. These coordinates have been compared with a preliminary estimate by the Applied Physics Laboratory using 39 passes of AN/SRN-9 Doppler data from three satellites. Two independent estimates were obtained using the NONAME Orbit Determination Program; one was from optical flash sequence data taken at the Minitrack Optical Tracking Station (MOTS) located at Madagascar and designated 1TANAN (40 inch camera) during July 1966 and the other from range measurements taken at MADGAR during November 1965. These two estimates of the site location are within 5 meters of each other, whereas the Applied Physics Laboratory estimate is separated by 50 meters, mainly in longitude. The comparison of the Applied Physics Laboratory MADGAR location estimate with the optically determined NONAME estimate is shown by plots of the residual differences of the range and rate measurements from five reference orbits determined solely from optical flash sequence data, and having a maximum root mean square of fit of less than 2 seconds of arc. The residual differences for both range and range rate measurements clearly indicate that a significantly better set of MADGAR coordinates was obtained from the NONAME Orbit Determination Program.

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INTRODUCTION

The coordinates of the two Satellite Tracking and Data Acquisition Network (STADAN) tracking stations in Tananarive, Madagascar, were estimated separately, using two independent data sets. The stations are the Minitrack Optical Tracking System (MOTS) 40 inch camera station 1TANAN and the Goddard Range and Range Rate (GRARR) station at Madagascar (MADGAR). The new locations were estimated using the NONAME Orbit Determination Program[1]; the data used in the estimation process were tracking data from Smithsonian Astrophysical Observatory (SAO) Baker-Nunn cameras, STADAN MOTS 40 inch cameras, and a STADAN range and range rate instrument. The location of each station was estimated separately using independent data sets; a data set from July 1966 was used to estimate 1TANAN, and another from November 1965 was used to estimate MADGAR.

The estimated locations are compared with the original in Table 1. The variations between the original and estimated coordinates were: 6.9 seconds in latitude for 1TANAN and 6.8 seconds for MADGAR; -0.3 and -0.2 second, respectively, in east longitude and 50.4 and 53.1 meters, respectively, in spheroid height. Thus, the relative location of the two stations has changed only slightly.

Table 1

Coordinates of 1TANAN and MADGAR.

Coordinates	1TANAN	MADGAR
Latitude		
Original	-19° 0' 26.4"	-19° 1' 12.6"
Estimated	-19° 0' 33.3"	-19° 1' 19.4"
Variation	+ 6.9"	+ 6.8"
East longitude		
Original	47° 17' 59.2"	47° 18' 8.2"
Estimated	47° 17' 58.9"	47° 18' 8.0"
Variation	- 0.3"	-0.2"
Spheroid height	(meters)	
Original	1305.5	1329.5
Estimated	1355.9	1382.6
Variation	50.4	53.1

The variations between the original coordinates and the estimated coordinates of 1TANAN were applied to the original MADGAR coordinates to obtain the optical estimate of the MADGAR location. In Table 2, this optical estimate is compared with both the NONAME GRARR MADGAR estimate and the APL estimate.

[1] Wolf Research and Development Corporation, "Interim Status Report on Program Development and GEOS-A Data Analysis," NASA Contract NAS 5-9756-44A, 55, 71, August 1967.

Table 2

Estimated MADGAR C-5 Station Coordinates
(GRARR S-band Antenna).

Estimate	Latitude	East longitude	Spheroid height
Optical	-19° 1' 19.5"	47° 18' 7.9"	1379.9
GRARR	-19° 1' 19.4"	47° 18' 8.0"	1382.6
APL	-19° 1' 19.5"	47° 18' 6.2"	1381.0

(The C-5 ellipsoid semimajor axis is 6,378,165 meters, and the flattening is 1/298.25.)

DETERMINATION OF STATION LOCATIONS

Orbits were estimated from two data sets using the NONAME Orbit Determination Program, operating in the data reduction mode. The program used a Bayesian least-squares technique to estimate six orbital parameters and the three coordinates of the station being estimated. The following data sets were used:

1. July 9, 10, and 11, 1966 using 730 measurements
2. November 28 and 29, 1965 using 598 measurements.

The majority of the measurements were from SAO Baker-Nunn camera stations; the remainder were from STADAN MOTS 40 inch camera stations and MADGAR GRARR.

The coordinates of 1TANAN were estimated using data set 1, and the coordinates of MADGAR were estimated using data set 2. The geometry of the passes over 1TANAN and MADGAR is represented in Figure 1. The data sets are summarized in Tables 3 and 4

COMPARISON OF STATION LOCATIONS

To compare the new locations, the original, NONAME, and APL coordinates[2] of MADGAR were used in turn to obtain the residual differences for ten passes of GRARR observations from five reference orbits.

The reference orbits were estimated using optical data only, and they all had an rms of fit of 2 seconds of arc or less. The following periods and data sets were used:

1. November 23 and 24, 1965, using 519 measurements
2. November 27, 28, and 29, 1965, using 826 measurements
3. November 28 and 29, 1965, using 574 measurements
4. July 17 and 18, 1966, using 780 measurements
5. July 22, 23, and 24, 1966, using 641 measurements.

These data sets are summarized in Tables 5 to 9.

[2]This is a preliminary result obtained by APL under a NASA contract.

Table 3

Summary of Data by Station for July 9, 10, and 11, 1966.

Station	No. of measurements	
	Right ascension	Declination
1TANAN	14	14
1ROSMA	7	7
1COLBA	14	14
1BPOIN	14	14
1DENVR	20	20
1JOBUR	14	14
1ORGAN	91	91
1OLFAN	28	28
1SPAIN	21	21
1QUIPA	28	28
1CURAC	28	28
1JUPTR	35	35
1VILDO	7	7
AUSBAK	14	14
1MAUIO	28	28
EDWAFB	2	2
Total	365	365

Table 4

Summary of Data by Station for November 28 and 29, 1965.

Station	No. of measurements	
	Right ascension	Declination
1ORGAN	59	59
1OLFAN	1	1
1SPAIN	1	1
1QUIPA	2	2
1CURAC	96	96
1JUPTR	127	127
1VILDO	1	1
Total	287	287
MADGAR	24 range measurements	

Table 5

Summary of Data by Station for November 23 and 24, 1965.

Station	No. of measurements	
	Right ascension	Declination
1EDINB	17	10
1FTMYR	41	44
1PURIO	19	19
1BPOIN	11	13
1BEDFRE	13	13
1ORGAN	62	55
1CURAC	59	51
1JUPTR	34	34
1COLBA	4	2
1OLFAN	3	2
1SPAIN	2	2
1QUIPA	1	1
1VILDO	3	3
AUSBAK	0	1
Total	269	250

Table 6

Summary of Data by Station for November 27, 28, and 29, 1965.

Station	No. of measurements	
	Right ascension	Declination
1EDINB	12	14
1FTMYR	21	21
1COLBA	10	11
1JUM40	6	6
1ORGAN	66	73
1SPAIN	1	1
1QUIPA	133	128
1JUPTR	169	148
1VILDO	2	2
AUSBAK	1	1
Total	422	406

Table 7

Summary of Data by Station for November 28 and 29, 1965.

Station	No. of measurements	
	Right ascension	Declination
1ORGAN	60	60
1OLFAN	1	1
1SPAIN	1	1
1QUIPA	2	2
1CURAC	96	96
1JUPTR	127	127
1VILDO	1	1
Total	288	288

Table 8

Summary of Data by Station for July 17 and 18, 1966.

Station	No. of measurements	
	Right ascension	Declination
1JOBUR	13	13
1ORGAN	73	73
1OLFAN	31	31
1SPAIN	48	48
1QUIPA	21	21
1JUPTR	112	112
1VILDO	14	14
1MAUIO	29	29
AUSBAK	49	49
Total	390	390

Table 9

Summary of Data by Station for July 22, 23, and 24, 1966.

Station	No. of measurements	
	Right ascension	Declination
1ORGAN	145	163
1OLFAN	31	35
1SPAIN	31	35
1QUIPA	27	27
1VILDO	21	21
1MAUIO	15	13
AUSBAK	49	
Total	319	322

The geometry of the ten GRARR passes during these periods is shown in Figures 2 and 3; the residual differences obtained using the three locations are summarized in Figures 4 to 23. The range residuals in these figures have been corrected for refraction, transponder delay, and known cable bias; no corrections were applied to the range rate residuals. Figures 4 to 23 clearly indicate that the NONAME estimated coordinates are a significant improvement over the other two sets.

The residuals obtained using the NONAME location are smaller in 16 out of the 20 plots by as much as 45 meters in range and 50 cm/sec in range rate in some cases. In three of the plots, the size of the residuals is approximately equal, and in one plot the residuals obtained using the APL location are slightly smaller. The sizes of the differences between the two sets of residuals correspond to the 50-meter separation in the longitude coordinate in combination with the pass geometry. However, after several private communications with individuals at APL, it was felt that there was a difference in the reference of the two sets of earth-fixed coordinate systems which were used in the determinations. The off set in the two earth-fixed coordinate systems was considered to be approximately 40 meters in longitude, i.e., in the appropriate direction which in turn would decrease the differences of the two estimates from 50 meters to 10 meters.

Goddard Space Flight Center
National Aeronautics and Space Administration
Greenbelt, Maryland, August 14, 1968
311-07-21-01-51

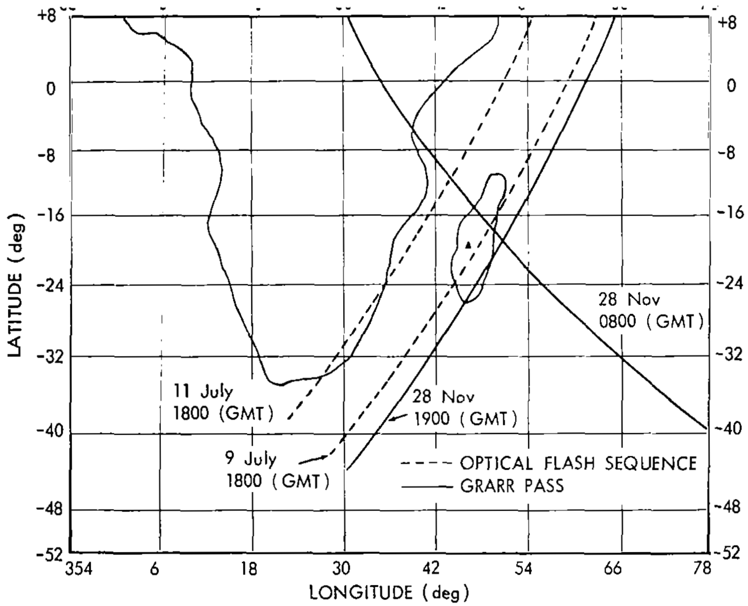

Figure 1—Optical and GRARR passes over Tananarive.

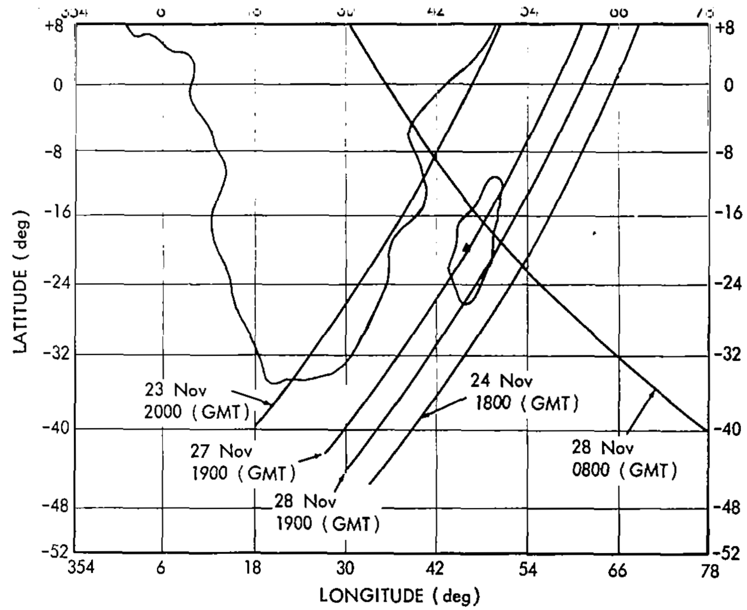

Figure 2—GRARR passes over MADGAR, November 1965.

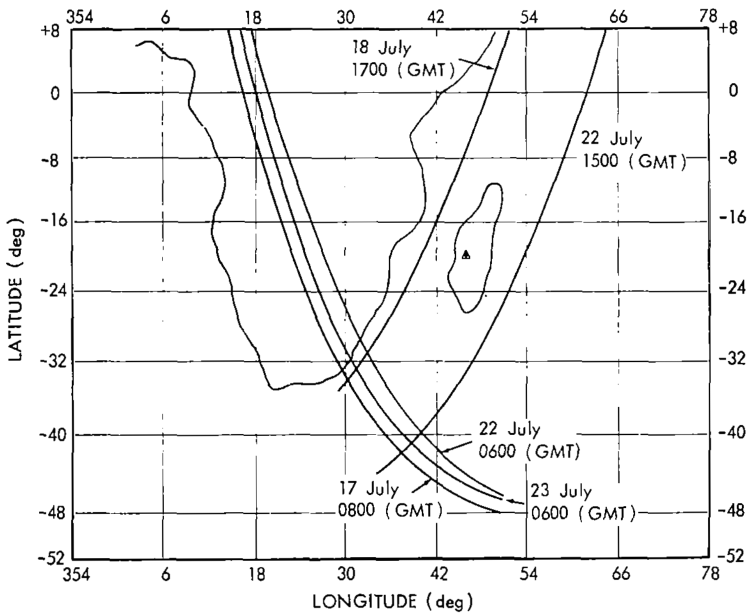

Figure 3—GRARR passes over MADGAR, July 1966.

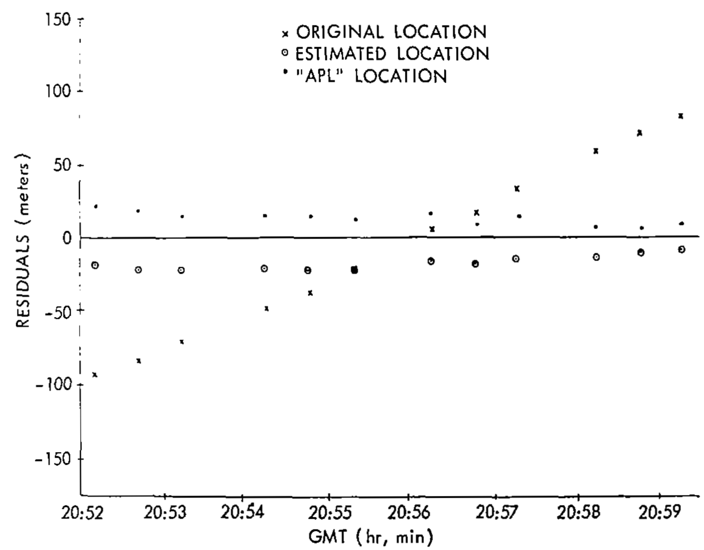

Figure 4—Range residuals from MADGAR, November 23, 1965.

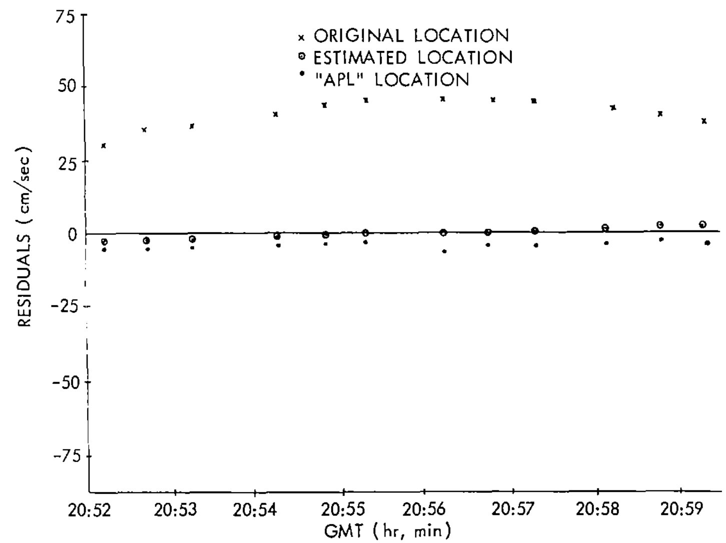

Figure 5—Range rate residuals from MADGAR, November 23, 1965.

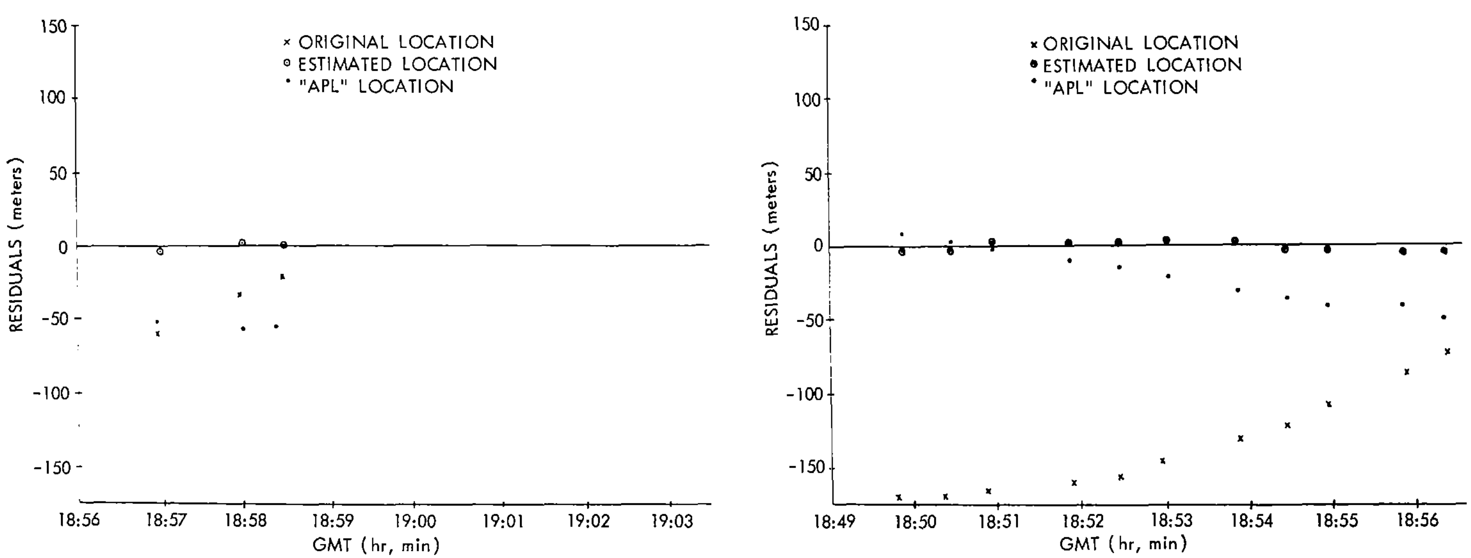

Figure 6—Range residuals from MADGAR, November 24, 1965.

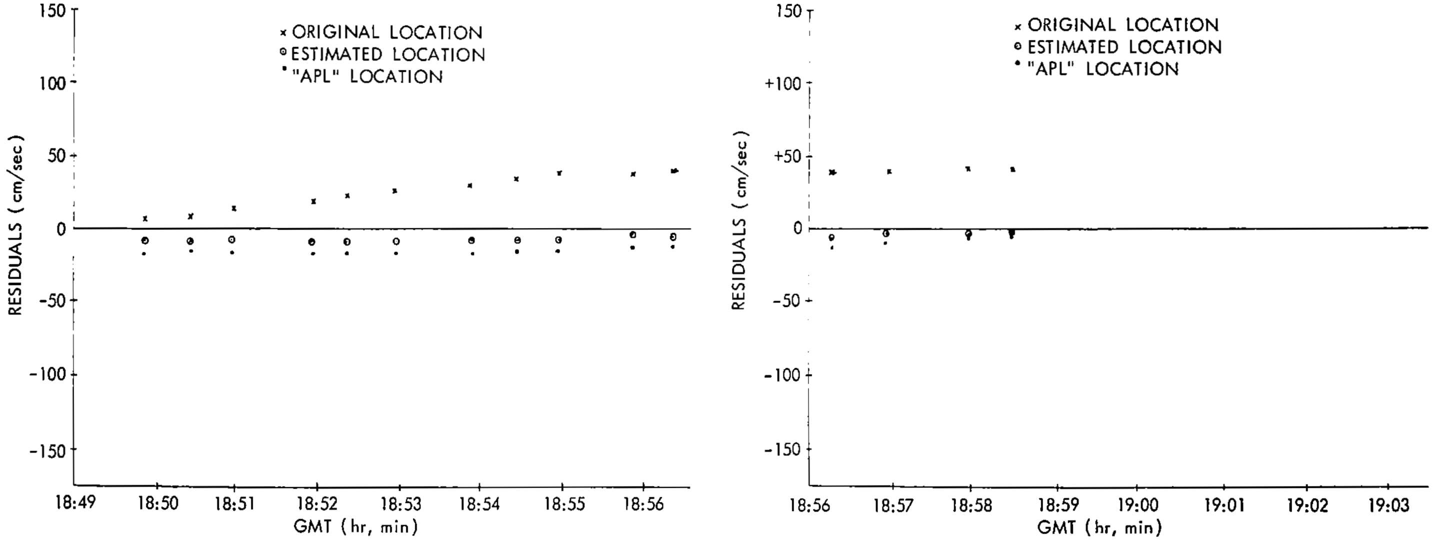

Figure 7—Range rate residuals from MADGAR, November 24, 1965.

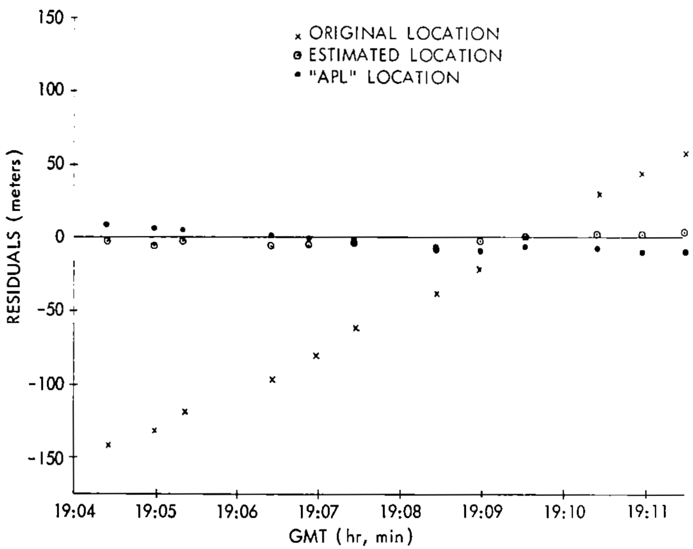

Figure 8—Range residuals from MADGAR, November 27, 1965.

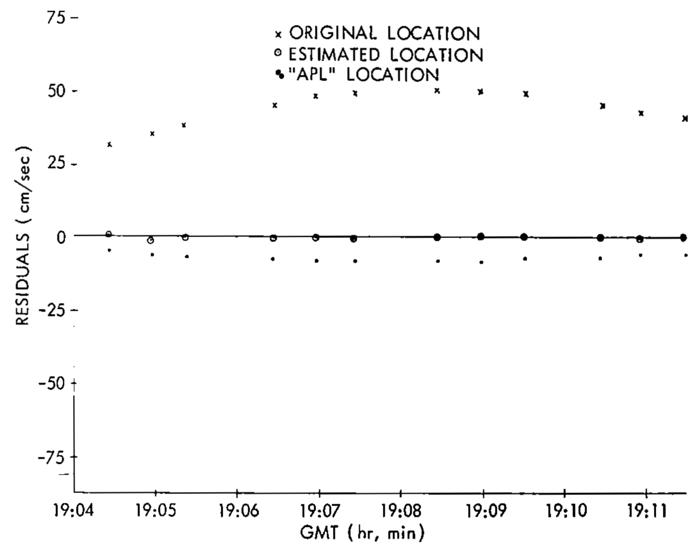

Figure 9—Range rate residuals from MADGAR, November 27, 1965.

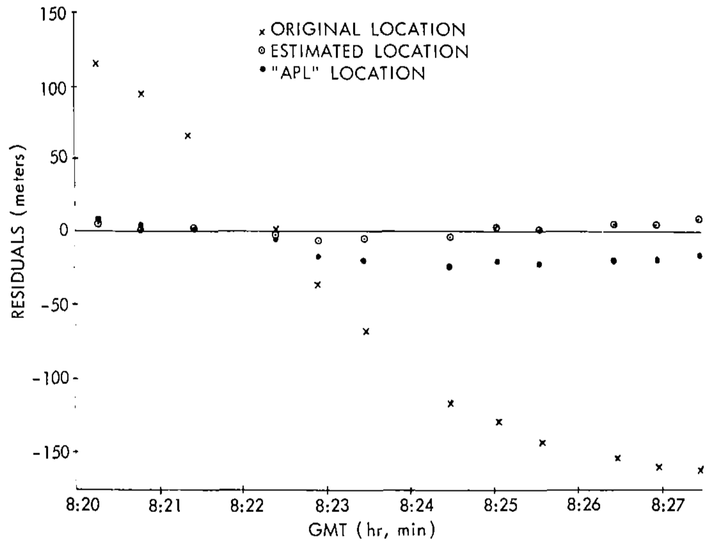

Figure 10—Range residuals from MADGAR, November 28, 1965.

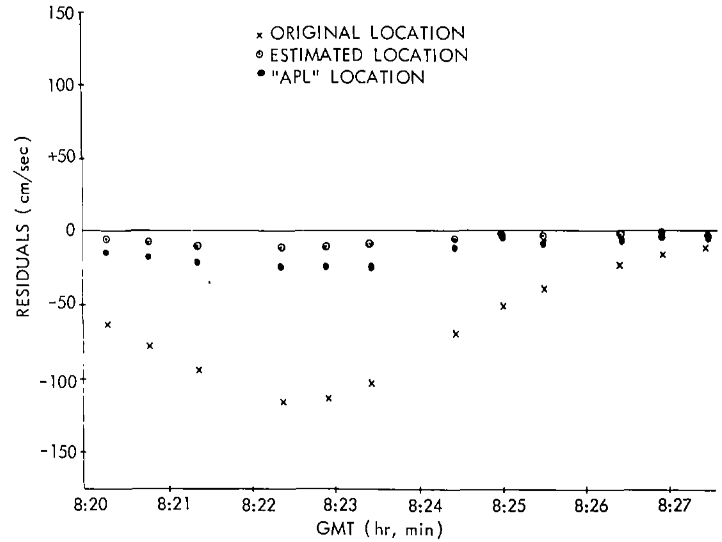

Figure 11—Range rate residuals from MADGAR, November 28, 1965.

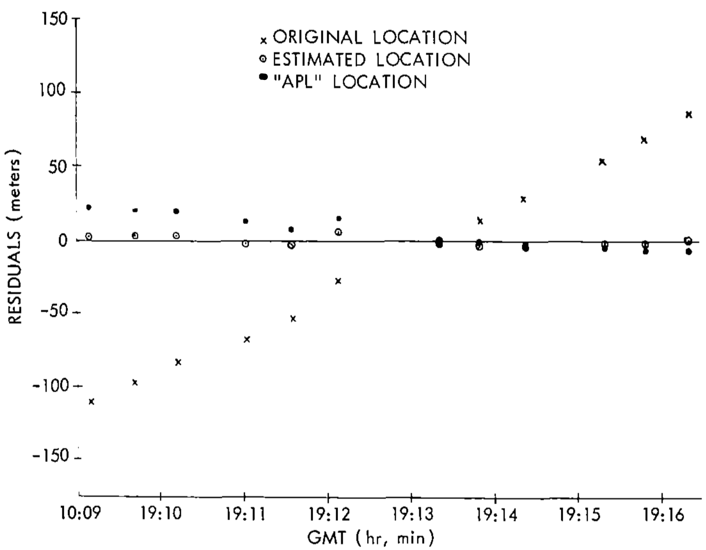

Figure 12—Range residuals from MADGAR, November 28, 1965.

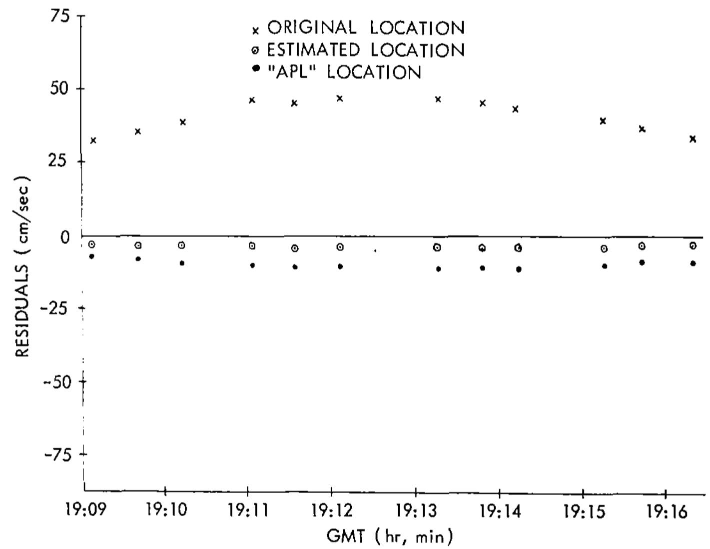

Figure 13—Range rate residuals from MADGAR, November 28, 1965.

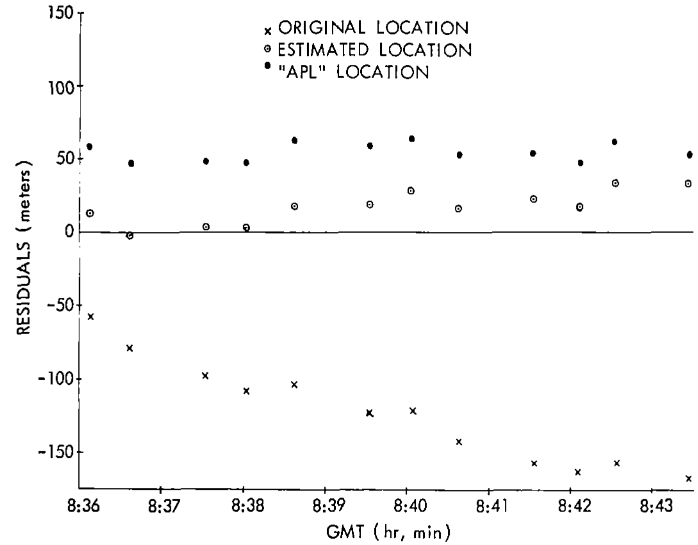

Figure 14–Range residuals from MADGAR, July 17, 1966.

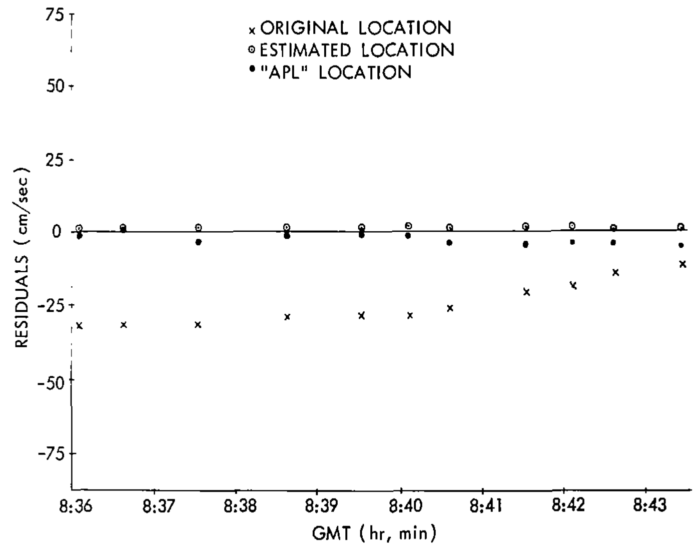

Figure 15–Range rate residuals from MADGAR, July 17, 1966.

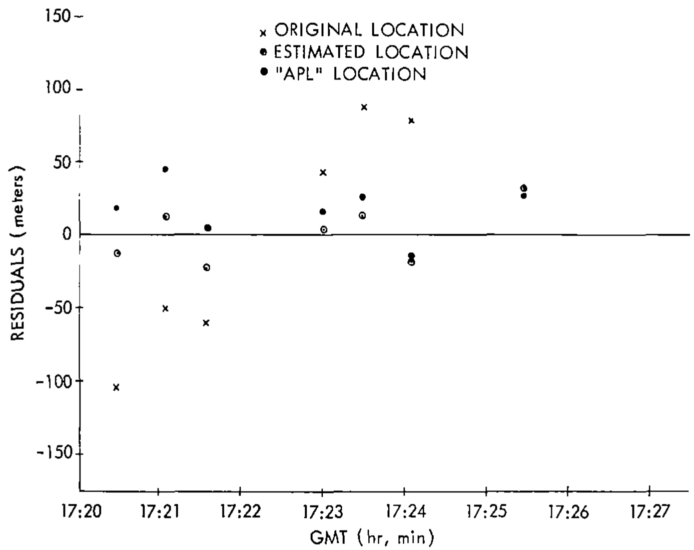

Figure 16–Range residuals from MADGAR, July 18, 1966.

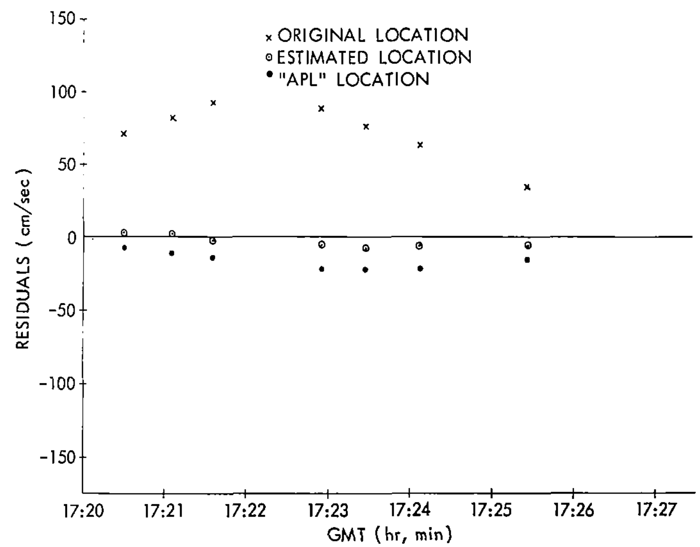

Figure 17–Range rate residuals from MADGAR, July 18, 1966.

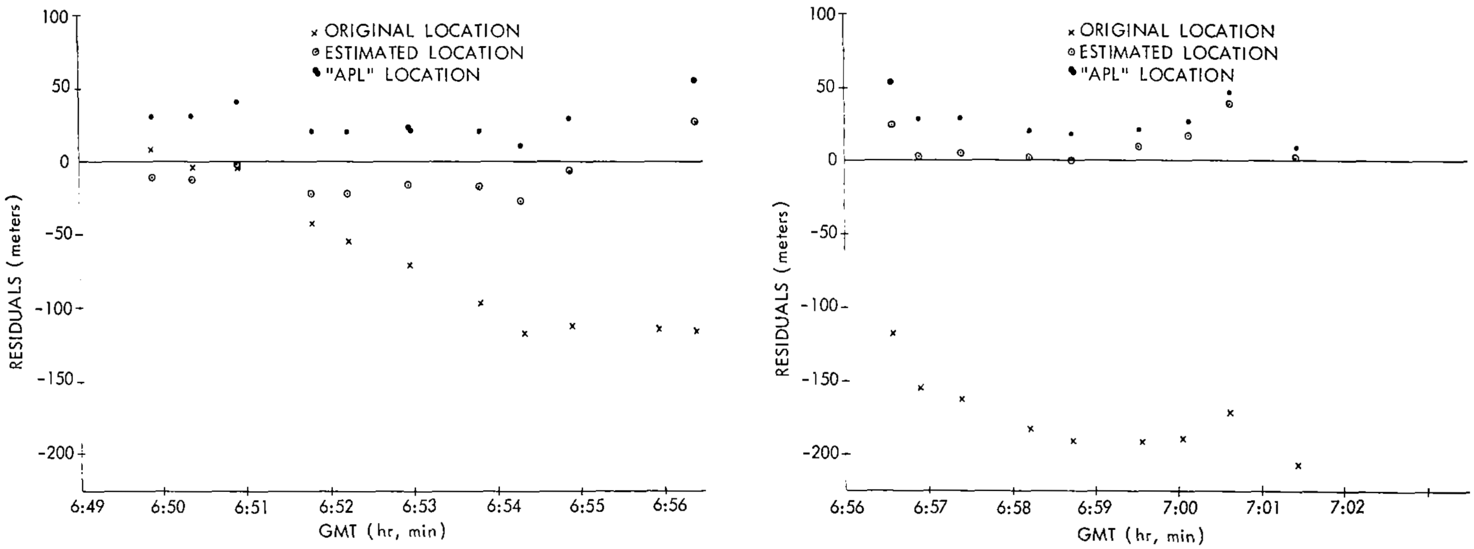

Figure 18–Range residuals from MADGAR, July 22, 1966.

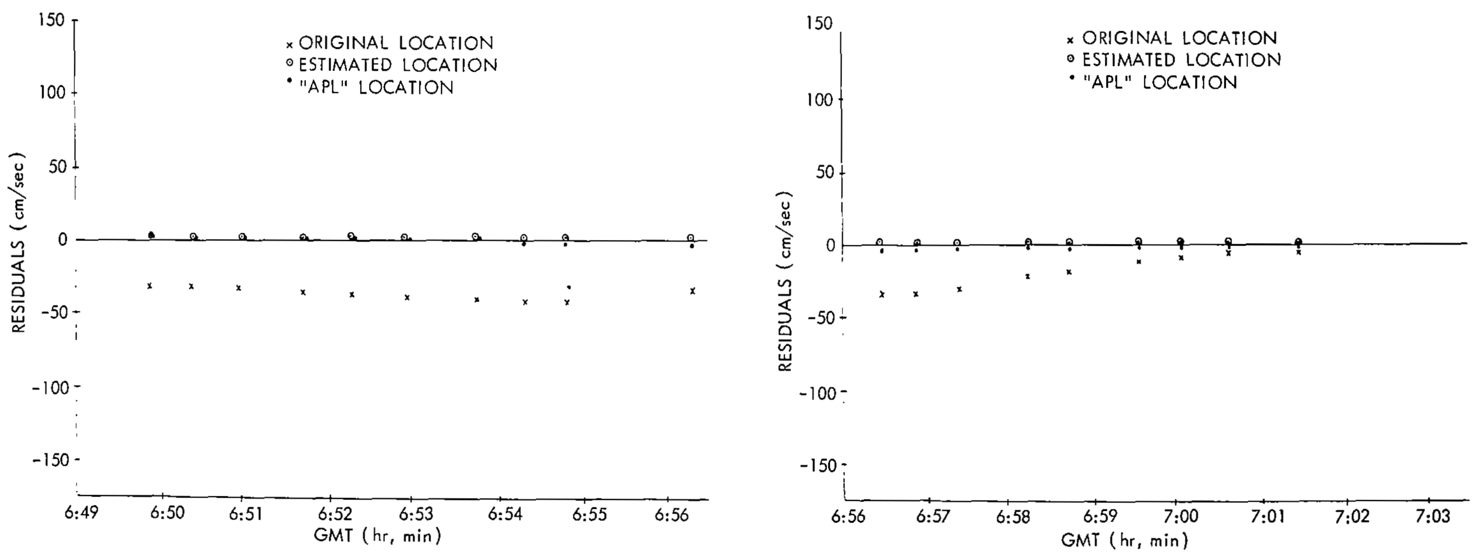

Figure 19–Range rate residuals from MADGAR, July 22, 1966.

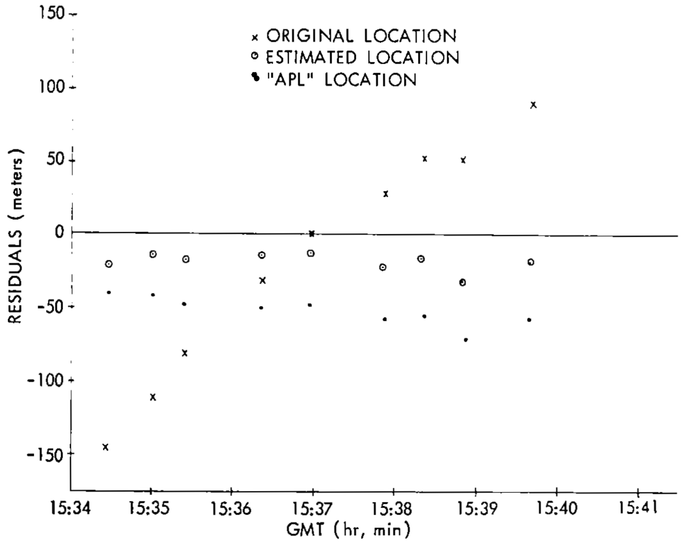

Figure 20—Range residuals from MADGAR, July 22, 1966.

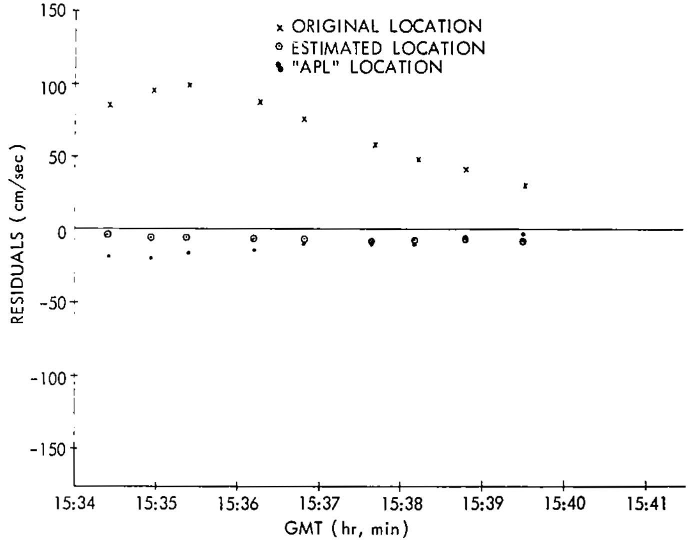

Figure 21—Range rate residuals from MADGAR, July 22, 1966.

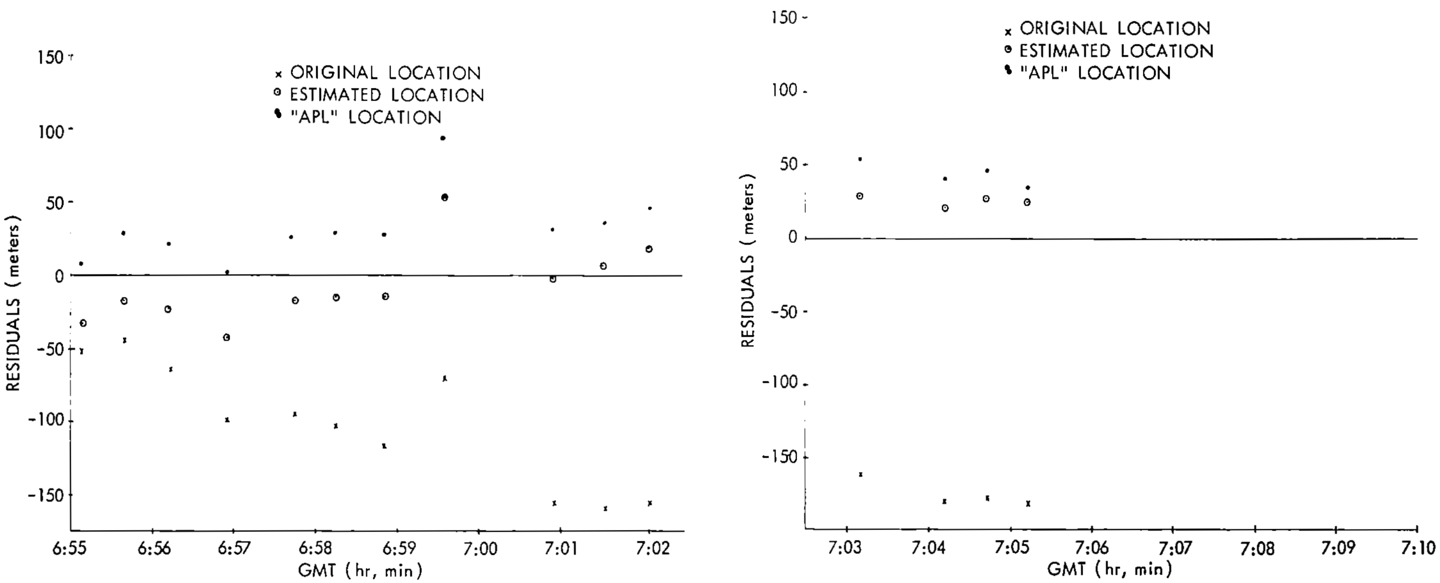

Figure 22—Range residuals from MADGAR, July 23, 1966.

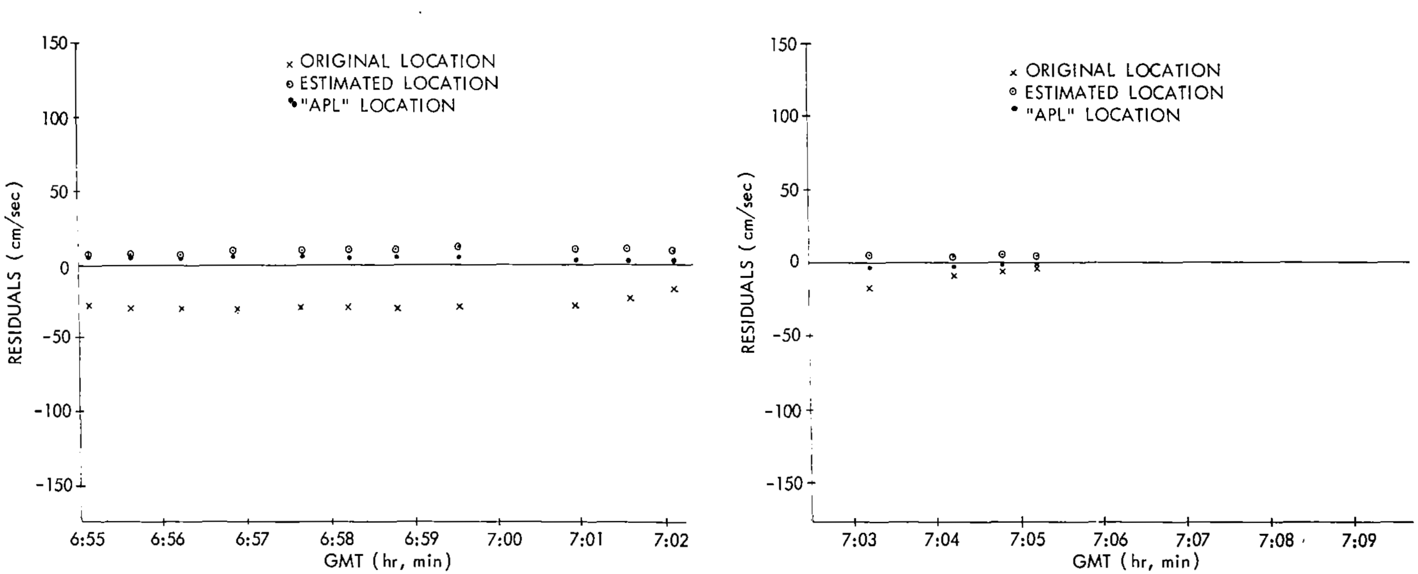

Figure 23—Range rate residuals from MADGAR, July 23, 1966.

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